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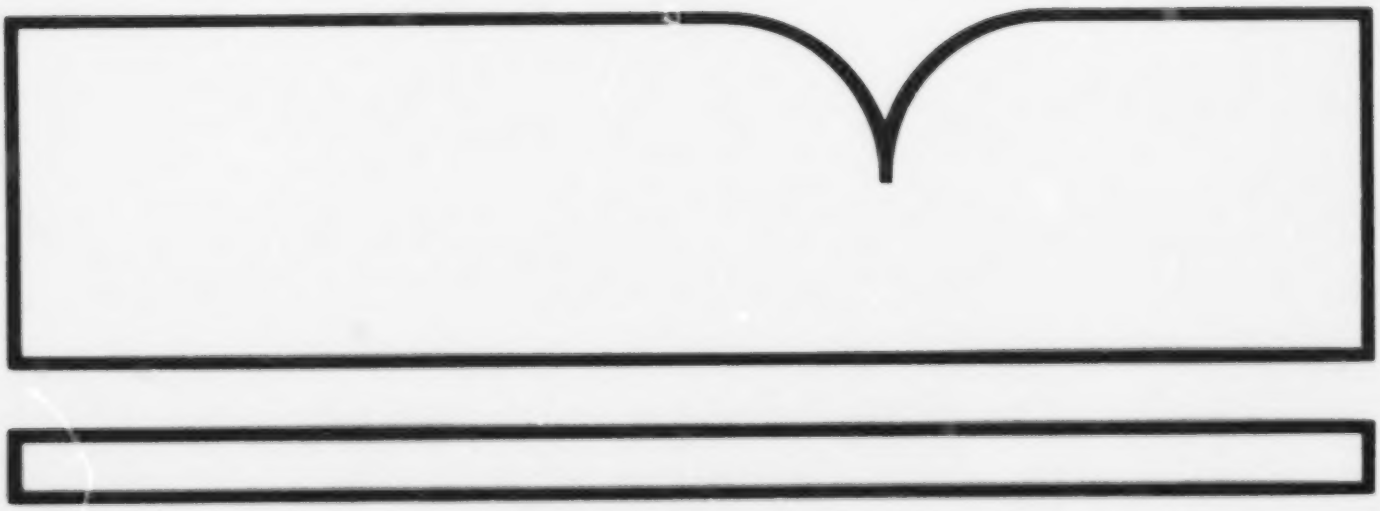

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U.S. EPA WASTEWATER DISINFECTION RESEARCH PROGRAM EVOLUTION TO A DESIGN MANUAL

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Albert D. Venosa
U.S. Environmental Protection Agency
Wastewater Research Division
Water Engineering Research Laboratory
Cincinnati, Ohio 45268

WATER ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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16. ABSTRACT

This paper presents the history of the EPA wastewater disinfection research program from the early 1970's until it culminated with the publication of the Process Design Manual in September 1986. The program was elevated to the highest Agency research priority in 1976 with the infusion of over $1 million additional funds to accelerate development of alternative technologies. Reasons given for this supplemental funding included the findings that chlorine was toxic to aquatic life in low concentrations and reacted with precursors to produce potentially hazardous halogenated organic compounds. A number of projects were funded and each briefly discussed in the paper. Alternative technologies that became fully developed include ozone and ultraviolet light. Finally, the design manual, its organization and purpose, the project team, and the four years of hard work leading up to final publication are discussed.

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U.S. EPA WASTEWATER DISINFECTION RESEARCH PROGRAM--EVOLUTION TO A DESIGN MANUAL

by

ALBERT D. VENOSA

In 1972, Congress enacted the Federal Water Pollution Control Act to "...restore and maintain the chemical, physical, and biological integrity of the nation's waters." For the purpose of enacting the FWPCA, the level of effluent reduction achievable by secondary treatment was to be defined by EPA. The Secondary Treatment Information Regulation was promulgated by EPA in August, 1973, as Part 133 of Title 40 of the Code of Federal Regulations (40 CFR 133). Included in the definition of secondary treatment were limitations on biochemical oxygen demand (BOD), suspended solids (SS), pH, and fecal coliform bacteria (FC).

At the time the Secondary Treatment Regulation was promulgated, the principal public comments received concerning the FC bacteria limitations took the view that disinfection is not a secondary treatment process, and therefore, the bacteria requirements should be deleted. Numerous issues were raised. The comments were directed primarily at the use of chlorine and the impact of 40 CFR 133, although some of the concerns related more generally to disinfection practice as a whole. The issues raised included the following:

1. Aquatic toxicity
2. Halogenated organics
3. Disinfection where possibility of human contact was remote
4. Excess energy use
5. Costs
6. Transportation and handling risks.

In January, 1974, an EPA Task Force was formed to review policy on wastewater disinfection and the use of chlorine. The Task Force concluded that the use of chlorine should be limited to situations where it is necessary to protect public health, the exclusive use of chlorine for disinfection should not be continued where protection of aquatic life is of primary consideration, alternative disinfection processes are not ready for widespread use, and the Secondary Treatment Regulation should be amended to provide flexibility in the disinfection requirements.

A final Task Force Report[1] was prepared to provide a compilation of the existing technical and scientific data related

to the issues raised by wastewater disinfection. As a result of this Task Force report, the EPA decided to delete the FC limitation from the definition of secondary treatment and rely on State water quality criteria to establish disinfection practices in the U.S. This decision was published in the Federal Register in the summer of 1976[2].

The impact of this decision on EPA's wastewater disinfection program was important. In 1976, a special Congressional research supplement was issued to accelerate development of disinfection technologies alternative to chlorine. Total research funds devoted to disinfection in that year amounted to $1.18 million, which represented approximately 3 times the amount normally allocated to that program during those years. This necessitated careful planning of a comprehensive research program that would achieve EPA's objectives.

DEVELOPMENTS IN THE DISINFECTION RESEARCH PROGRAM PRIOR TO 1976

Prior to 1976, the disinfection program was already underway. The largest single disinfection project ever funded was the Wyoming, Michigan project, which actually began in 1971. The purpose of this project was to compare the disinfection efficiency and the induced acute and chronic toxicity of the same effluent receiving different disinfectant treatments. Two sites were selected for study, Wyoming, Michigan, and Grandville, Michigan. The disinfection systems compared were chlorination, chlorination/dechlorination, chlorobromination, ozonation, and no disinfection at all. All systems were installed on side streams of the same effluent, so that the only variable between treatments was the type of disinfectant. The project lasted five years, and substantial amounts of data were gathered, especially fish toxicity data. The final report and journal articles published then are still referenced in papers today[3,4].

Other projects that were already underway prior to the infusion of research funds in 1976 include:

1. A pilot scale investigation of UV disinfection at the City of Dallas Water Reclamation Research Center[5]. Prior to that, another small scale project had just been completed at St. Michaels, Maryland[6].

2. A pilot scale investigation of ozone disinfection at the Pomona, California wastewater treatment plant[7].

3. A project conducted by Utah State University evaluating the effectiveness of the Logan, Utah multi-cell lagoon in removing fecal coliforms with and without intermittent sand filtration and with and without chlorine disinfection[8].

DEVELOPMENTS IN THE DISINFECTION RESEARCH PROGRAM AFTER 1976

With the infusion of the Congressional supplement in Fiscal Year 1976, several projects were funded that might not have been funded had the extra dollars not been provided. These projects were:

1. A pilot scale investigation of a submerged quartz UV system at the University of North Carolina, Chapel Hill. The purpose of this project was to compare the effectiveness of UV in disinfecting filtered and unfiltered secondary effluent and to develop a means of measuring dose[9].

2. A full scale investigation of a state-of-the-art UV system being installed at the Northwest Bergen County Water Pollution Control Plant, Waldwick, New Jersey[10]. This was the first project of such magnitude ever conceived involving ultraviolet light disinfection, and it represented a great deal of risk because the technology was far from being "proven."

3. A direct outgrowth of the UV projects above was the award given to the City of New York to develop specific design guidelines for UV disinfection systems. This turned out to be the most important project conducted for direct input into the design manual. All the major state-of-the-art UV systems were evaluated extensively at the City's Port Richmond treatment facility on Staten Island, and a mathematical model was developed incorporating the effects of flow hydraulics, dispersion, and UV intensity on expected performance[11].

4. Two full scale demonstration projects of ozone disinfection, one at Estes Park, Colorado[12], and the other at Meander, Ohio[13].

5. An investigation of a brand new ozone generation technology, the electron beam accelerator, that was claimed able to generate ozone at one-fourth to one-fifth the energy expenditure as conventional corona discharge generators. The idea fizzled almost as quickly as it started, as the electron beam accelerator could not generate ozone at sufficient concentrations in air to be practical. The project was salvaged, however, when it was decided to evaluate the turbine aspirating ozone contactor manufactured by Kerag[14]. Very useful data were generated in this project, much of which was used in the current design manual discussed below. The project was conducted at the Marlborough, Massachusetts wastewater treatment plant.

6. An evaluation of the ablility of chlorine, ozone, and ultraviolet light in inactivating animal viruses under full scale conditions. The proprietary virus concentration and enumeration procedure developed by the Carborundum Company was used in gathering the needed data[15].

7. A basic research study with Stanford University investigating adsorption/inactivation of viruses on metal oxide surfaces was funded to see if a novel means of disinfection conceived at Stanford could be made feasible for use in water or wastewater treatment[16].

8. A bench scale investigation of chlorine dioxide disinfection was conducted at Stanford University to compare the cost-effectiveness of chlorine dioxide with chlorine on secondary effluent[17].

9. A project with Oak Ridge National Laboratory was funded to determine the change in chemical constituency of primary and secondary effluents exposed to chlorine, ozone, and UV light at disinfection doses. The data were especially useful in evaluating the risks associated with the use of these disinfectants when treating secondary effluents[18].

10. The University of Colorado at Denver was awarded funds to perform a risk assessment of alternative wastewater disinfectants. Disinfectants selected for study were chlorine, ozone, and ultraviolet light. The purpose was to determine if there was a sufficient data base to develop a mathematical model predicting the risks associated with the use of a given disinfectant under given circumstances[19].

11. A project with the Los Angeles County Sanitation Districts was funded to evaluate the cost-effectiveness of sulfur dioxide, activated carbon, and holding ponds to provide a toxicity-free effluent at a reasonable cost to the user. Pilot studies were conducted and surveys performed to determine the operation and maintenance requirements of dechlorination systems currently in operation[20].

12. A major investigation was conducted with the State of California on the optimization of chlorination systems. An idealized mobile chlorination system was designed and built and then taken to eight full-scale treatment facilities in California to determine how much savings in chlorine use and reduction in induced aquatic toxicity could be achieved simply by better design[21,22].

13. The in-house research effort was bolstered by the initiation of a major ozone contactor optimization study that continued until 1984. Data that were generated in that program subelement were directly used in the resulting design manual. The publications developed over those eight years are too numerous to cite here.

14. Two symposiums were held, one in 1978[23] and another in 1982[24], to bring together all the data from the above projects and present them in some coherent fashion to the scientific and engineering communities prior to embarking on the design manual project.

15. James Montgomery Engineers was awarded a research contract to conduct a Technical Evaluation of existing ultraviolet light disinfection systems operating across the country. Interviews were conducted with operators and designers, and actual data collected at selected facilities on effectiveness of cleaning devices and appropriateness of mathematical model parameter values developed in the New York City Port Richmond study[25].

DESIGN MANUAL

The project for the preparation of the wastewater disinfection design manual was authorized to start on June 21, 1982. The project team that was assembled to develop the manual was composed of engineers who had been active in the field over the past decade and who had developed a high degree of expertise in specific areas of disinfection. Dr. Enos L. Stover, Oklahoma State University, became the team leader and was responsible for writing the first four chapters of the manual. Those chapters involve discussion of the objectives of the manual, background and historical development of the various disinfection systems included in the manual, need for alternative disinfection technologies, and disinfection kinetics and reactions. Dr. Stover's primary background was in ozone disinfection kinetics and contactor and generator design.

Dr. Charles N. Haas, Illinois Institute of Technology, was responsible for the halogenation chapter. The chapter includes discussion of chlorination (gaseous and liquid systems), hypochlorination, on-site chlorine generation, chlorine dioxide disinfection, bromochlorination, and dechlorination. Dr. Haas's primary background was in the kinetics of chlorine and chloramine disinfection in aqueous systems.

Kerwin L. Rakness, Process Applications, Inc., was responsible for the ozonation chapter. The chapter summarizes all the known information about the operation and maintenance

requirements of ozone systems, design of gas pre-treatment and contactor systems, and sizing of generator and ancillary equipment. Mr. Rakness's background involved heading up the Estes Park, Colorado project and design of the Vail, Colorado ozone disinfection facility.

O. Karl Scheible, HydroQual, Inc., was responsible for writing the ultraviolet light disinfection chapter. The section summarizes all the background work leading to development of the mathematical model used in design sizing of UV equipment, the necessary hydraulics considerations, how to calculate average UV intensity in any geometric configuration of lamps, and the known operation and maintenance needs and problems of UV systems. Mr. Scheible's background included serving as principal investigator on the NW Bergen County demonstration project, the New York City UV design project, and consultant to the James Montgomery Technical Evaluation project.

The Wastewater Disinfection Process Design Manual represents the culmination of all the research projects mentioned above that have been conducted over the last 12 to 15 years. The project team worked hard incorporating as much of the data as possible. The five years it took to finalize the manuscript were well worth the expenditure, for the manual now represents the most authoritative and up-to-date document on disinfection design in existence today. Although certainly not all the questions on disinfection have been answered, the EPA has no more plans to support further research on wastewater disinfection in the near future as other research priorities have displaced disinfection as being more critical to the Agency's needs.

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Author. Albert D. Venosa is a research microbiologist with the U.S. Environmental Protection Agency, Water Engineering Research Laboratory, Office of Research and Development, Cincinnati, Ohio.

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